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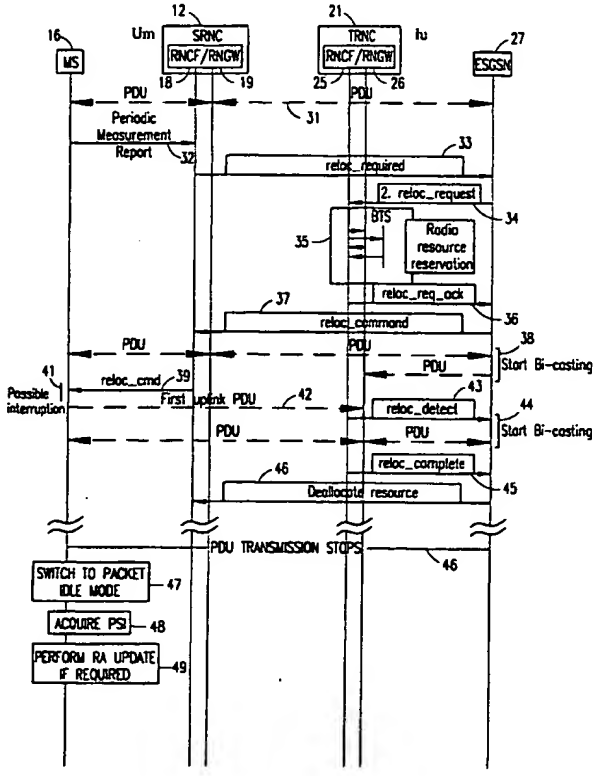
[Continued on next page]

(54) Title: RAPID HANDOVER OF A MOBILE STATION BETWEEN RADIO NETWORK CONTROLLERS ACCESSING AN ENHANCED GENERAL PACKET RADIO SERVICE (EGPRS) NETWORK



(57) Abstract: A Radio Access Network (RAN) (10) and method for rapid handover of a mobile station between a Source Radio Network Controller (SRNC) (12) and a Target Radio Network Controller (TRNC) (21) in the RAN. A mobile station (16) initially served by the SRNC accesses an Enhanced General Packet Radio Service (EGPRS) network (27) through the RAN for conducting a packet-switched call. When handover to the TRNC is required, the SRNC notifies the TRNC that relocation of the mobile station to the TRNC is requested. The TRNC reserves radio resources required to serve the mobile station in the TRNC, and notifies the SRNC that relocation is approved. An Iux interface (11) may be established between the SRNC and the TRNC for direct communication of control signaling. Alternatively, the control signaling between the SRNC and the TRNC may pass through the EGPRS network. The EGPRS begins bi-casting Packet Data Units (PDUs) (44) to both the SRNC and the TRNC until notified by the TRNC that the handover is complete (45). The mobile station is then handed over to the TRNC, and the EGPRS network is notified by the TRNC that the handover is complete. With the Iux interface (11), control signaling that is specific to the RAN does not have to be passed through the EGPRS network.

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RAPID HANDOVER OF A MOBILE STATION BETWEEN RADIO NETWORK CONTROLLERS ACCESSING AN ENHANCED GENERAL PACKET RADIO SERVICE (EGPRS) NETWORK

PRIORITY STATEMENT UNDER 35 U.S.C. § 119(e) & 37 C.F.R. § 1.78

This nonprovisional application claims priority based upon the prior U.S. provisional patent application entitled, "Method of Rapid Handover of Mobile Stations Between Radio Network Controllers in an Enhanced General Packet Radio Service Network", application number 60/160,240 filed October 18, 1999, in the names of Kumar Balachandran, Peter Galyas, Marlene Yared, Martin Adams, and Jean-Francois Bertrand.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

This invention relates to telecommunication systems and, more particularly, to a method of rapid handover of a mobile station between radio network controllers accessing an Enhanced General Packet Radio Service (EGPRS) network.

Description of Related Art

The General Packet Radio Service (GPRS) is a packet-switched network for the transfer of high-speed and low-speed data and signaling between mobile stations (MSs) and other terminal equipment. The MSs may access the GPRS network through various Radio Access Networks (RANs). Althought GPRS was orignally designed to operate with the Global System for Mobile Communications (GSM), strict separation is maintained between the RAN and the core GPRS network, allowing the core GPRS network to be reused with other radio access technologies.

Enhanced GPRS (EGPRS) networks are enhanced with a technology called Enhanced data rates for GSM Evolution (EDGE). In such networks, MSs access the EGPRS network through an EGPRS Radio Access Network (ERAN), and the controlling entity within the EGPRS network is an Enhanced Serving GPRS Service Node (ESGSN). Various interfaces are now being defined between the ERAN and the

EGPRS network. The GSM 2.5 standard defined an interface based on the Gb interface and frame relay, while the Universal Mobile Telecommunications Systems (UMTS) standard (a third generation cellular standard relating to the evolution of GSM and EDGE) defined an IP-based interface utilizing the Iu interface. EDGE has defined the Iu-PS' interface which is a packet-switched interface related to the UMTS Iu interface.

The existing and proposed interfaces between the ERAN and the EGPRS network, however, experience excessive handover delay when handing over a mobile station from one Radio Network Controller (RNC) to another within the ERAN. The resultant interruption time is a serious problem for real-time applications which are delay-sensitive. It would be advantageous to have a handover method, and an interface for use with the method that reduces the interruption time during inter-RNC handover to a level that is acceptable for real-time applications. The present invention presents such a method and interface.

SUMMARY OF THE INVENTION

In one aspect, the present invention is a method of rapid handover of a mobile station between a Source Radio Network Controller (SRNC) and a Target Radio Network Controller (TRNC) in a Radio Access Network through which the mobile station accesses an Enhanced General Packet Radio Service (EGPRS) network. The mobile station is involved in an on-going call transferring Packet Data Units (PDUs) through the EGPRS network via the SRNC. The method includes the steps of notifying the TRNC by the SRNC that relocation of the mobile station to the TRNC is requested; reserving by the TRNC, radio resources required to serve the mobile station in the TRNC; and notifying the SRNC by the TRNC that relocation of the mobile station to the TRNC is approved. An Iux interface may be established between the SRNC and the TRNC for direct communication of control signaling. Alternatively, the control signaling between the SRNC and the TRNC may pass through the EGPRS network. This is followed by notifying the EGPRS network that a handover is taking place from the SRNC to the TRNC. The EGPRS then begins bi-casting PDUs to both the SRNC and the TRNC until notified by the TRNC that the

handover is complete. The mobile station is then handed over to the TRNC, and the EGPRS network is notified by the TRNC that the handover is complete.

In another aspect, the present invention is a Radio Access Network (RAN) for providing mobile stations with access to an EGPRS network. The RAN includes a first Radio Network Controller (RNC) that provides service to the mobile stations through at least one Base Transceiver Station (BTS). The RAN also includes a second RNC that provides service to the mobile stations through at least one BTS, and an Iux interface between the first RNC and the second RNC for passing control signaling. The Iux interface may pass, for example, relocation messages between the first RNC and the second RNC when one of the mobile stations is handed over from the first RNC to the second RNC. In this manner, control signaling that is specific to the RAN does not have to be passed through the EGPRS network.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and its numerous objects and advantages will become more apparent to those skilled in the art by reference to the following drawings, in conjunction with the accompanying specification, in which:

FIG. 1 is a simplified block diagram of an EGPRS Radio Access Network (ERAN) in which the Iux interface of the present invention has been implemented;

FIG. 2 is a signal flow diagram illustrating the flow of messages when performing an inter-RNC handover of a mobile station in a first embodiment of the method of the present invention when the Iux interface is not implemented in the ERAN; and

FIG. 3 is a signal flow diagram illustrating the flow of messages when performing an inter-RNC handover of a mobile station in a second embodiment of the method of the present invention when the Iux interface is implemented in the ERAN.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention is method of reducing the handover delay and the interruption time when handing over a mobile station from a Source RNC (SRNC) to a Target RNC (TRNC) in an EGPRS Radio Access Network (ERAN). As noted

above, it is critical for delay-sensitive, real-time applications that the interruption time be minimized.

FIG. 1 is a simplified block diagram of an ERAN 10 in which the Iux interface 11 of the present invention has been implemented. The ERAN includes an SRNC 12 which controls base transceiver stations (BTSs) 13-15. BTS 14 is currently serving a mobile station (MS) 16 which is operating with terminal equipment (TE) 17. Functionally, the SRNC includes a Radio Network Control Function (RNCF) 18 and a Radio Network Gateway (RNGW) 19. Control signaling passes through the RNCF while user (payload) information passes through the RNGW.

Also illustrated in FIG. 1 is a TRNC 21 to which the MS 16 is being handed over. The TRNC controls BTSs 22-24. Like the SRNC, the TRNC functionally includes an RNCF 25 and an RNGW 26. The SRNC 12 and the TRNC 21 are connected with the new Iux interface 11. Both the SRNC and the TRNC are connected to the core EGPRS network (represented by the ESGSN 27) through an Iu-PS' interface. Within each RNC, the Iu-PS' interface is divided into a control interface (Iu-PS'-C) which interfaces with the RNCF, and a user interface (Iu-PS'-U) which interfaces with the RNGW.

The Iux interface 11 is normally utilized to transfer control signaling rather than payload information from the SRNC to the TRNC. In certain circumstances, however, payload information may also be transferred over the Iux interface. For example, for loss-sensitive traffic, PDUs may be queued in the SRNC during the handover interruption, and then forwarded to the TRNC. Since it would be inefficient to relay those PDUs via the core network, the Iux interface may be used to transfer queued PDUs to the TRNC.

FIG. 2 is a signal flow diagram illustrating the flow of messages when performing an inter-RNC handover of the MS 16 from SRNC 12 to TRNC 21 in a first embodiment of the method of the present invention when the Iux interface is not implemented in the ERAN 10. There are 2 vertical lines below the SRNC and the TRNC, representing signaling in the control plane and the user plane. The control plane signaling is shown to pass through the RNCF 18 in the SRNC, and through the RNCF 25 in the TRNC. The user (payload) information passes through the RNGW

19 in the SRNC, and through the RNGW 26 in the TRNC. The ESGSN 27 represents the core EGPRS network.

At 31, a PDU (packet) transmission is in process. The MS 16 sends periodic measurement reports 32 to the SRNC 12 regarding the radio conditions. At some point, the signal strength gets weak enough to initiate a handover to another cell. If there is no Iux interface, a Relocation Required message 33 is sent from the SRNC to the ESGSN and identifies the TRNC. The ESGSN sends a Relocation Request 34 to the identified TRNC. At 35, the TRNC performs a radio resource reservation procedure in order to speed up the handover process by identifying and reserving the necessary radio resources ahead of time. The TRNC determines the availability of radio resources required to serve the MS in the TRNC, and reserves the resources if they are available.

When the radio resources are reserved, the TRNC sends a Relocation Request Acknowledgment message 36 back to the ESGSN. The ESGSN then sends a Relocation Command message 37 to the SRNC. Both the Relocation Request Acknowledgment message and the Relocation Command are enhanced to carry information about the target cell resources that were reserved, the time slot on which transmission will be continued, and any other information needed by the MS for the radio access in the target cell.

If the TRNC determines that radio resources are not available, a failure indication is returned to the ESGSN in the Relocation Request Acknowledgment message 36. The ESGSN, in turn, sends the failure indication to the SRNC in the Relocation Command message 37. The SRNC then determines from the periodic measurement reports 32 which TRNC is the next best candidate for handover. The next best TRNC is then selected, and the process is repeated until the SRNC finds a TRNC capable of serving the MS, or it has to drop/drag the call.

The relocation signaling through this point does not have any impact on PDU transmission, which continues through all of these steps. Assuming 30 ms per message and 50 ms for the radio resource reservation procedure, a total of approximately 170 ms is spent preparing the network for handover.

After the Relocation Command message 37 is sent, the ESGSN starts bi-

casting the PDUs to both the SRNC and the TRNC at 38. This minimizes any interruption in the packet flow when the handover takes place. The SRNC then sends a Relocation Command message 39 to the MS, providing all of the control information needed by the MS to effectuate the handover (timing advance, time slot, uplink and downlink channels, triggering event, Temporary Flow Identifier, etc.). Approximately 20-40 ms is required to send the Relocation Command.

The MS then leaves its serving cell and enters the target cell. There is a possible interruption of 20-60 ms during the time that the actual switching is performed for the handover at 41 due to cell-switching and re-synchronization, if needed. In an alternative embodiment, the TRNC may buffer PDUs during the interruption to minimize packet loss. However, real-time applications are more delay-sensitive than they are loss-sensitive, and therefore there is no buffering in the preferred embodiment. When the first uplink PDU is sent from the MS to the TRNC at 42, it triggers a handover detection in the TRNC, and causes the TRNC to send a Relocation Detect message 43 to the ESGSN. This requires about 30 ms. This causes the ESGSN to stop the bi-casting of the PDUs at 44, and send them only to the TRNC.

The handover is then complete, and a Relocation Complete message 45 is sent from the TRNC to the ESGSN, requiring approximately 30 ms. The ESGSN then sends a Deallocate Resource message 46 to the SRNC which makes the radio resources previously used by the MS available to other users. This message does not contribute to the handover delay/interruption.

The entire procedure takes about 330 ms with only about 60 ms of interruption for the actual switching. Even with a safety factor of two, to account for possible channel errors and ERAN congestion, a handover interruption time of less than 120 ms should be achievable under all reasonable circumstances.

At some later time, the data session ends, and PDU transmission stops at 46. The MS then switches from packet transfer mode to idle mode at 47, and begins acquisition of the Packet System Information (PSI) in the new cell at 48. The MS also realizes a possible Routing Area (RA) change and at 49, initiates an RA Update procedure, if required.

FIG. 3 is a signal flow diagram illustrating the flow of messages when

performing an inter-RNC handover of the MS 16 from SRNC 12 to TRNC 21 in a second embodiment of the method of the present invention when the Iux interface 11 is implemented in the ERAN 10. Like FIG. 2, signaling through the SRNC and the TRNC is identified as control plane signaling or user plane (payload) signaling.

At 51, a PDU (packet) transmission is in process. The MS 16 sends periodic measurement reports 52 to the SRNC 12 regarding the radio conditions. At some point, the signal strength gets weak enough to initiate a handover to another cell. Since the Iux interface is implemented to carry control signals between the SRNC and the TRNC, a Relocation Required message 53 is sent from the SRNC directly to the TRNC using the Iux interface. At 54, the TRNC performs the radio resource reservation procedure in order to speed up the handover process by identifying and reserving the necessary radio resources ahead of time.

When the radio resources are reserved, the TRNC sends a Start Bi-casting Request message 55 to the ESGSN, and the ESGSN sends a Start Bi-casting Acknowledgment message 56 back to the TRNC. The ESGSN then starts bi-casting the PDUs to both the SRNC and the TRNC at 57 in order to minimize any interruption in the packet flow when the handover takes place. The TRNC then sends a Relocation Confirm message 58 to the SRNC over the Iux interface. The SRNC then sends a Relocation Command 59 to the MS, providing all of the control information needed by the MS to effectuate the handover.

Once again, there is a possible interruption of 20-60 ms during the time that the actual switching is performed for the handover at 61. When the first uplink PDU sent from the MS to the TRNC at 62, it triggers the TRNC to send a Relocation Detect message 63 to the ESGSN. This causes the ESGSN to stop the bi-casting of the PDUs at 64, and send them only to the TRNC. The handover is then complete, and a Relocation Complete message 65 is sent from the TRNC to the ESGSN. The TRNC then sends a Deallocate Resource message 66 over the Iux interface to the SRNC which makes the radio resources previously used by the MS available to other users.

Like the first embodiment, the entire procedure takes about 330 ms with only about 60 ms of interruption for the actual switching. Even with a safety factor of two, to account for possible channel errors and ERAN congestion, a handover interruption

time of less than 120 ms should be achievable under all reasonable circumstances. Thus, the advantage that the Iux interface offers is not in further reducing the handover delay, but rather in reducing the signaling load on the core EGPRS network, and in further separating radio access functionality from the core network.

If the first handover attempt fails, for example because the TRNC does not succeed in its attempt to reserve radio resources, the Relocation Confirm message includes an indication of failure. The SRNC then repeats the same procedure with other TRNCs until it finds a TRNC capable of serving the MS, or it has to drop/drag the call. The Iux interface is very efficient in this scenario since a significant number of messages do not have to go through the core EGPRS network.

At some later time, the data session ends, and PDU transmission stops at 67. The MS then switches from packet transfer mode to idle mode at 68, and begins acquisition of the Packet System Information (PSI) in the new cell at 69. The MS also realizes a possible Routing Area (RA) change and at 70, initiates an RA Update procedure, if required.

It is thus believed that the operation and construction of the present invention will be apparent from the foregoing description. While the ERAN and method shown and described has been characterized as being preferred, it will be readily apparent that various changes and modifications could be made therein without departing from the scope of the invention as defined in the following claims.

WHAT IS CLAIMED IS:

1. A method of rapid handover of a mobile station between a Source Radio Network Controller (SRNC) and a Target Radio Network Controller (TRNC) in a Radio Access Network through which the mobile station accesses an Enhanced General Packet Radio Service (EGPRS) network, said mobile station being involved in an on-going call transferring Packet Data Units (PDUs) through the EGPRS network via the SRNC, said method comprising the steps of:

notifying the TRNC by the SRNC that relocation of the mobile station to the TRNC is requested;

reserving by the TRNC, radio resources required to serve the mobile station in the TRNC;

notifying the SRNC by the TRNC that relocation of the mobile station to the TRNC is approved;

notifying the EGPRS network that a handover is taking place from the SRNC to the TRNC;

bi-casting PDUs by the EGPRS network to both the SRNC and the TRNC until notified by the TRNC that the handover is complete;

handing over the mobile station to the TRNC; and

notifying the EGPRS network by the TRNC that the handover is complete.

2. The method of rapid handover of claim 1 wherein the step of notifying the TRNC by the SRNC that relocation of the mobile station to the TRNC is requested includes the steps of:

sending a relocation required message from the SRNC to the EGPRS network; and

sending a relocation request message from the EGPRS network to the TRNC.

3. The method of rapid handover of claim 2 wherein the step of notifying the SRNC by the TRNC that relocation of the mobile station to the TRNC is approved includes the steps of:

sending a relocation request acknowledgment message from the TRNC to the EGPRS network; and

sending a relocation command message from the EGPRS network to the SRNC.

4. The method of rapid handover of claim 1 wherein the step of reserving radio resources by the TRNC includes the steps of:

determining whether radio resources are available in the TRNC to serve the mobile station; and

reserving the radio resources required to serve the mobile station in the TRNC upon determining that the radio resources are available.

5. The method of rapid handover of claim 4 further comprising, after the step of determining whether radio resources are available in the TRNC to serve the mobile station, the step of notifying the SRNC by the TRNC that the handover attempt failed, upon determining that the radio resources are not available in the TRNC.

6. The method of rapid handover of claim 5 further comprising, after the step of notifying the SRNC that the handover attempt failed, the steps of:

selecting by the SRNC, a second TRNC which is a next best candidate for handover of the mobile station; and

attempting to handover the mobile station to the second TRNC.

7. The method of rapid handover of claim 1 further comprising, before the step of handing over the mobile station, the step of sending, from the SRNC to the mobile station, information required by the mobile station for handover.

8. The method of rapid handover of claim 1 wherein the step of notifying the EGPRS network by the TRNC that the handover is complete includes sending a relocation detect message to the EGPRS network when a first uplink PDU is received from the mobile station by the TRNC.

9. The method of rapid handover of claim 1 further comprising the step of instructing the SRNC to deallocate any radio resources that were being utilized by the mobile station in the SRNC prior to the handover.

10. The method of rapid handover of claim 1 wherein an Iux interface is established between the SRNC and the TRNC for passing control signaling, and the step of notifying the TRNC by the SRNC that relocation of the mobile station to the TRNC is requested includes sending a relocation required message directly from the SRNC to the TRNC over the Iux interface.

11. The method of rapid handover of claim 10 wherein the step of notifying the SRNC by the TRNC that relocation of the mobile station to the TRNC is approved includes sending a relocation confirm message directly from the TRNC to the SRNC over the Iux interface.

12. The method of rapid handover of claim 1 further comprising the steps of:

ending the call;

switching the mobile station to packet-idle mode;

acquiring Packet System Information (PSI) by the mobile station in its new cell; and

initiating a Routing Area Update procedure by the mobile station, if required.

13. A method of rapid handover of a mobile station between a Source Radio Network Controller (SRNC) and a Target Radio Network Controller (TRNC) in a Radio Access Network through which the mobile station accesses an Enhanced General Packet Radio Service (EGPRS) network, said mobile station being involved in an on-going call transferring Packet Data Units (PDUs) through the EGPRS network via the SRNC, said method comprising the steps of:

implementing an Iux interface between the SRNC and the TRNC for passing control signaling;

notifying the TRNC by the SRNC that relocation of the mobile station to the TRNC is requested by sending a relocation required message directly from the SRNC to the TRNC over the Iux interface;

determining whether radio resources are available in the TRNC to serve the mobile station;

reserving the radio resources required to serve the mobile station in the TRNC upon determining that the radio resources are available;

notifying the SRNC by the TRNC that relocation of the mobile station to the TRNC is approved by sending a relocation confirm message directly from the TRNC to the SRNC over the Iux interface;

notifying the EGPRS network that a handover is taking place from the SRNC to the TRNC;

bi-casting PDUs by the EGPRS network to both the SRNC and the TRNC until notified by the TRNC that the handover is complete;

sending, from the SRNC to the mobile station, information required by the mobile station for handover;

handing over the mobile station to the TRNC; and

notifying the EGPRS network by the TRNC that the handover is complete.

14. The method of rapid handover of claim 13 further comprising instructing the SRNC to deallocate any radio resources that were being utilized by the mobile station in the SRNC prior to the handover by sending a deallocate resources message directly from the TRNC to the SRNC over the Iux interface.

15. The method of rapid handover of claim 13 further comprising, after the step of determining whether radio resources are available in the TRNC to serve the mobile station, the steps of:

notifying the SRNC that the handover attempt failed, upon determining that radio resources are not available in the TRNC to serve the mobile station;

selecting by the SRNC, a second TRNC which is a next best candidate for handover of the mobile station; and

attempting to handover the mobile station to the second TRNC.

16. The method of rapid handover of claim 13 further comprising the steps of:

ending the call;

switching the mobile station to packet-idle mode;

acquiring Packet System Information (PSI) by the mobile station in its new cell; and

initiating a Routing Area Update procedure by the mobile station, if required.

17. A Radio Access Network (RAN) for providing mobile stations with access to an Enhanced General Packet Radio Service (EGPRS) network, said RAN comprising:

a first Radio Network Controller (RNC) that provides service to the mobile stations through at least one Base Transceiver Station (BTS);

a second RNC that provides service to the mobile stations through at least one BTS; and

an Iux interface between the first RNC and the second RNC for passing control signaling.

18. The RAN of claim 17 wherein the Iux interface passes relocation messages between the first RNC and the second RNC when one of the mobile stations is handed over from the first RNC to the second RNC.

19. The RAN of claim 18 wherein the Iux interface also passes payload information between the first RNC and the second RNC.

20. The RAN of claim 19 wherein the first RNC includes means for buffering Packet Data Units (PDUs) during a handover interruption period, and the buffered PDUs are forwarded to the second RNC after handover of the mobile station is complete.

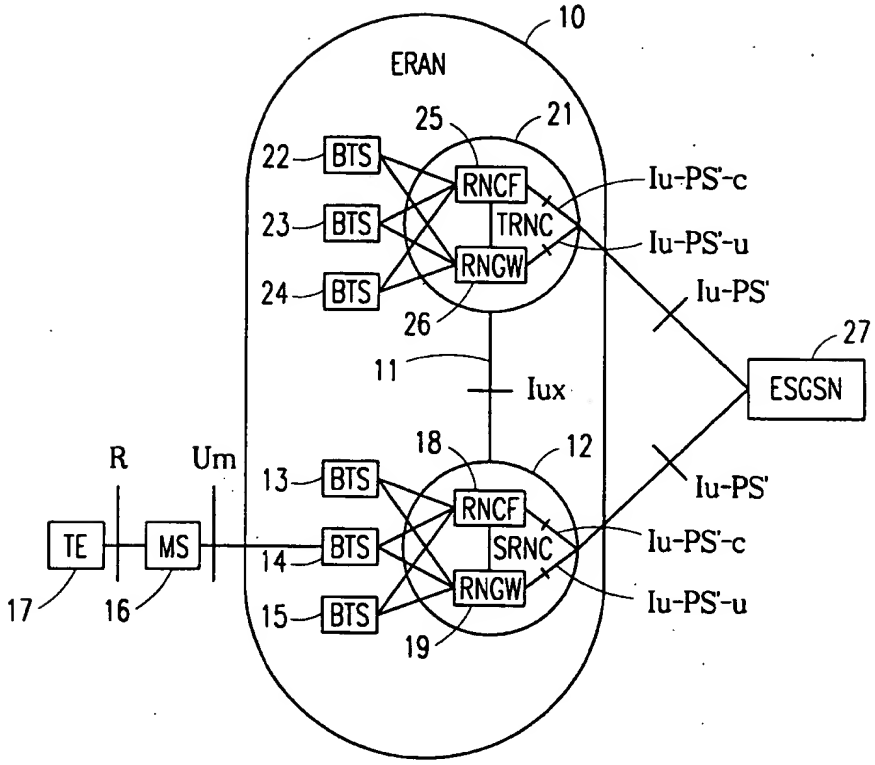
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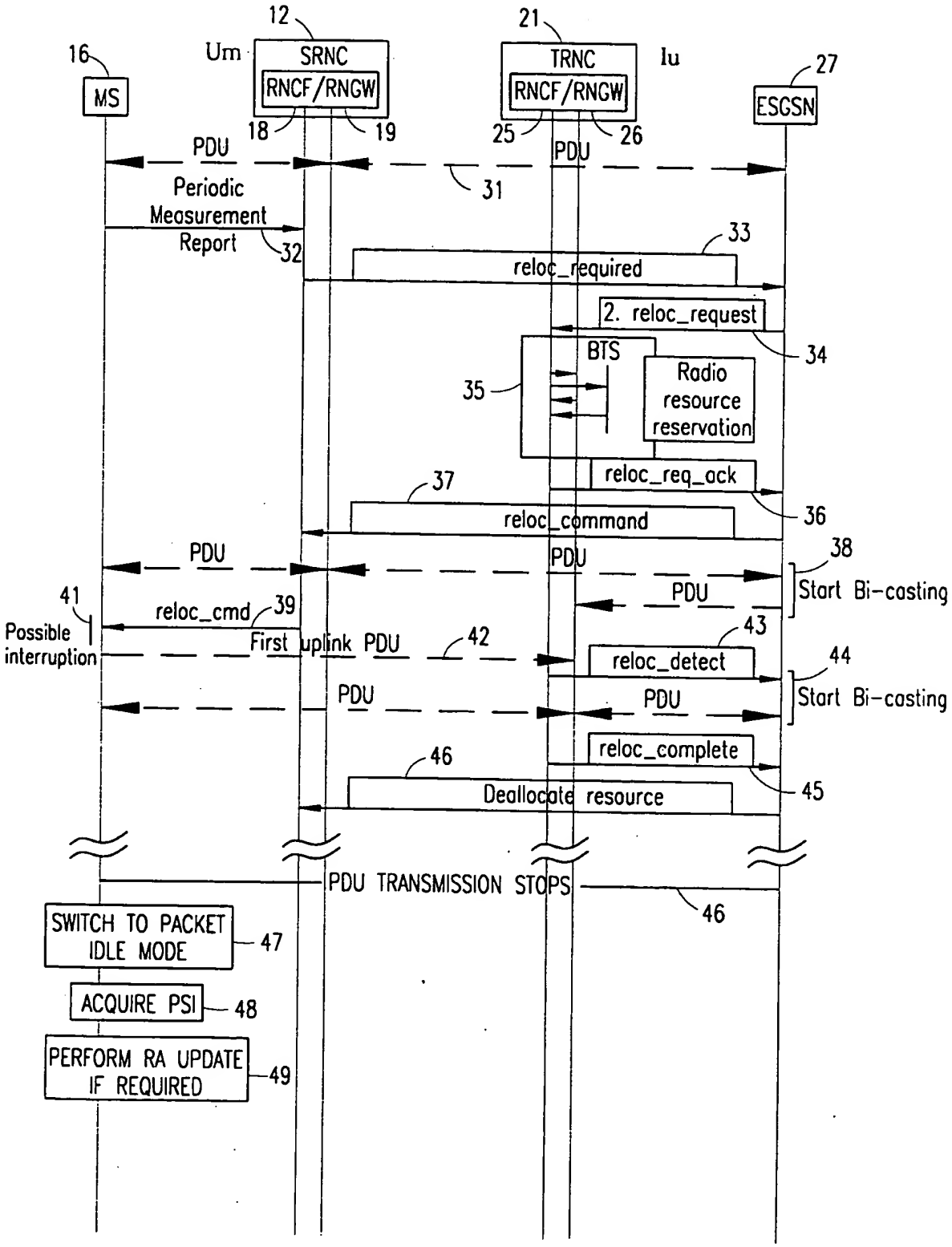
FIG. 1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43
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44
PDU
PDU
Start Bi-casting
reloc_complete
46
45
Deallocate resource
PDU TRANSMISSION STOPS
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SWITCH TO PACKET
IDLE MODE
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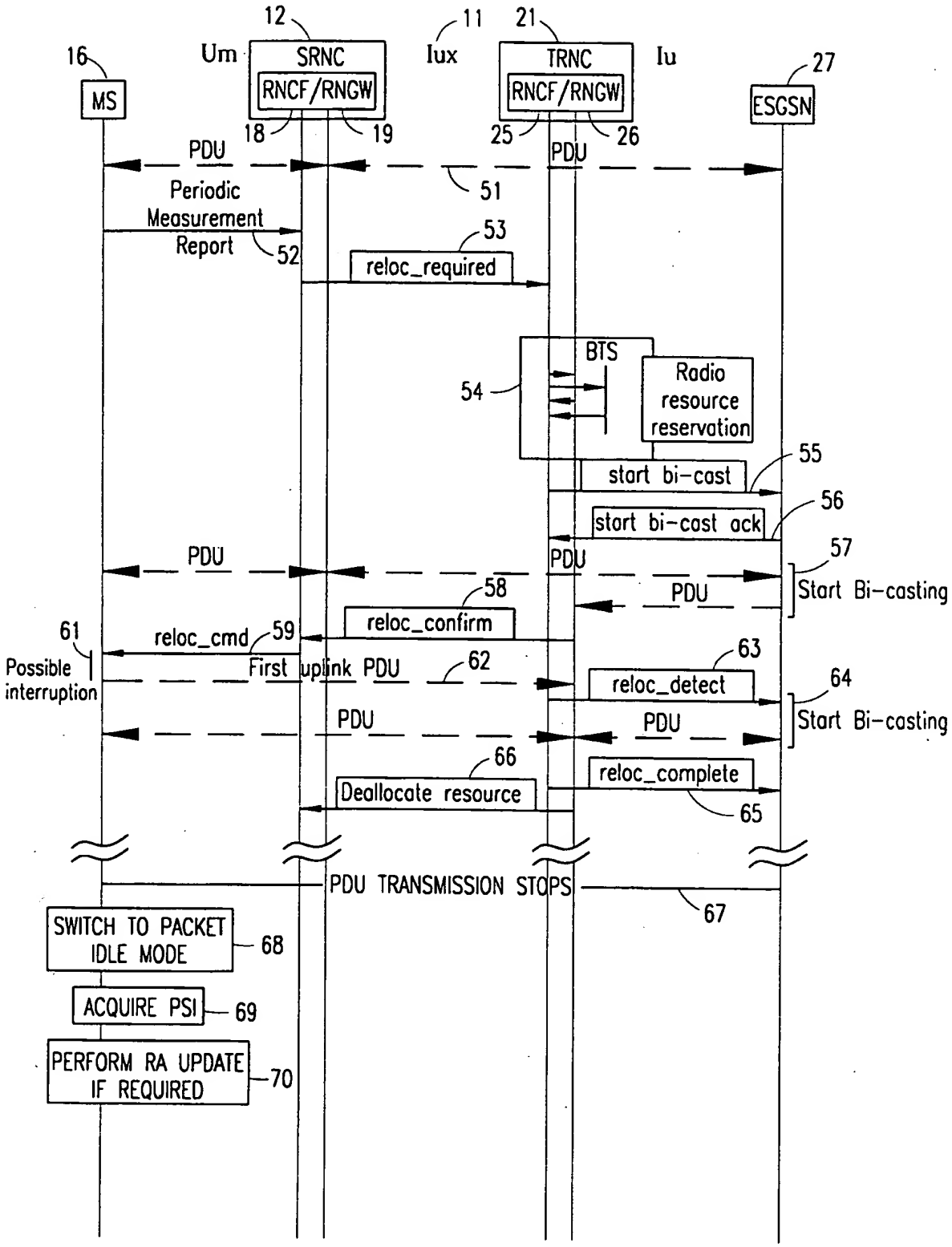
ACQUIRE PSI
48
PERFORM RA UPDATE
IF REQUIRED
49

FIG. 2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Deallocate resource
65
PDU TRANSMISSION STOPS
67
SWITCH TO PACKET
IDLE MODE
68
ACQUIRE PSI
69
PERFORM RA UPDATE
IF REQUIRED
70

FIG. 3